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(54) **Footwear with differential cushioning regions**

(57) A shoe having an upper and a sole (70), wherein the sole (70) includes differential cushioning regions to provide cushioning and stability for the wearer's foot. Cushioning elements (72,73;72',73') which exhibit different stiffnesses in compression are placed at selected locations with respect to the skeletal structure of the foot. Cushioning elements (72,72') with lesser stiffness are positioned at locations most likely to experience direct impact loading during running and like activities. Cushioning elements (73,73') with greater stiffness are positioned at locations where greater resistance is needed to provide stability.

A cushioning element (72;72') of lesser stiffness underlies at least a substantial portion of the ball (42) of the foot. A cushioning element (73;73') of higher relative stiffness comprises at least a roughly C-shape area of the sole (70) adjacent the medial side of the sole (70) and embracing a medial end portion of the cushioning element (72,72') of lesser stiffness.

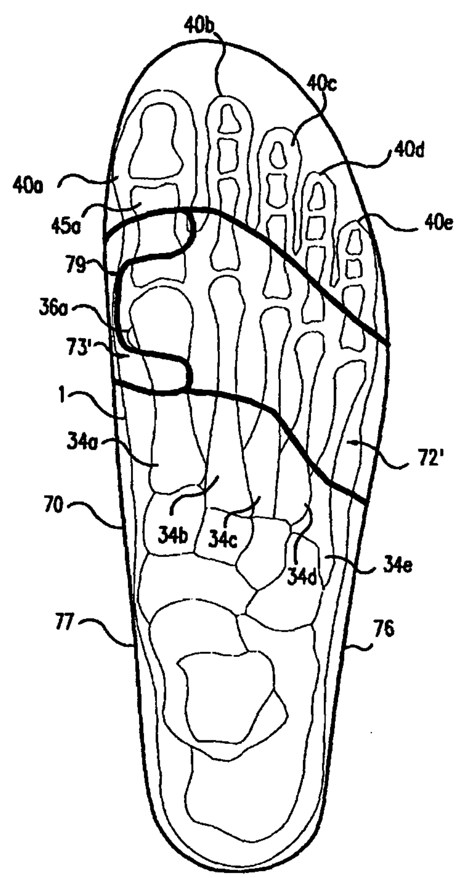

FIG.12

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Description

FIELD OF THE INVENTION

Th inv ntion p rtains to footwear, and especially athletic footwear, wherein the sole includes differential cushioning regions to provide both cushioning protection and stability for the wearer's foot.

BACKGROUND OF THE INVENTION

To provide cushioning protection and support for the foot, the sole of an athletic shoe commonly has a multilayer construction comprising an outsole, a midsole, and an insole. The outsole is normally formed of a resilient and durable material to resist wearing of the sole during use. In many cases, the outsole includes lugs, cleats or other elements to enhance the cushioning and traction afforded by the sole. The midsole ordinarily forms the middle layer of the sole and is typically composed of a soft foam material to attenuate and dampen impact energy and distribute pressure placed upon the foot during athletic activities. The midsole may be formed with or without the inclusion of other cushioning elements, such as resilient inflated bladders. An insole layer is usually a thin, padded member provided overtop of the midsole to enhance the comfort afforded to the wearer. The performance of such footwear depends in large part on the ability of the sole to effectively cushion applied loads relative to the anatomy and skeletal structure of the foot and to stabilize the movements associated with running and like activities.

The skeletal structure of a foot 1 provides the requisite strength to support the weight of the body through a wide range of activities (Figs. 1-4). The structure of the foot can be categorized into three areas - namely, rearfoot area 2, midfoot area 3, and forefoot area 4.

Rearfoot area 2 includes talus 13 and calcaneus 17. Tibia 10 and fibula 11 of the leg are movably attached to talus 13 to form the ankle joint. In general, leg bones 10, 11 form a mortise into which a portion of talus 13 is received to form a hinge-type joint which allows both dorsi and plantar flexion of the foot. Talus 13 overlies and is movably interconnected to calcaneus 17 to form the subtalar joint. The subtalar joint enables the foot to move in a generally rotative, side-to-side motion. Rearfoot pronation and supination of the foot is generally defined by movement about this joint.

Midfoot area 3 is anterior to rearfoot area 2 and comprises navicular 20, cuboid 21 and outer, middle and inner cuneiforms 22-24. The four latter bones 21-24 facilitate interconnection of the tarsus to the metatarsus.

Forefoot area 4 is anterior to midfoot area 3 and includes: proximal heads 31a, 31b, 31c, 31d, 31e, shafts 32a, 32b, 32c, 32d, 32e, and distal heads 33a, 33b, 33c, 33d, 33e of metatarsals 34a, 34b, 34c, 34d, 34e; metatarsal-phalangeal joints 35a, 35b, 35c, 35d, 35e; sesamoids 36a, 36b; and phalanges 45-47. For foot area 4 includes a ball area 42 and a toe area 43. Ball ar a 42 of the foot is g nerally considered to include sesamoids 36a-b, distal heads 33a-e, metatarsal-phalangeal joints 35a-e, proximal heads 44a, 44b, 44c, 44d, 44e of proximal phalanges 45a, 45b, 45c, 45d, 45e, and the anterior portions of shafts 32a-e of metatarsals 34a-e. Toe area 43 is generally considered to include distal phalanges 46a, 46b, 46c, 46d, 46e, middle phalanges 47b, 47c, 47d, 47e, and the distal heads 48a, 48b, 48c, 48d, 48e and shafts 49a, 49b, 49c, 49d, 49e of proximal phalanges 45a-e.

Each metatarsal 34a-e is aligned with and attached via connective tissue to one of the proximal phalanges 45a-e at metatarsal-phalangeal joints 35a-e. For example, first metatarsal 34a is connected to proximal phalange 45a of the big toe 40a, and fifth metatarsal 34e is connected to proximal phalange 45e of the smallest or fifth toe 40e. First, second and third metatarsals 34a-c are largely attached on their proximal ends to outer, middle and inner cuneiforms 22-24, respectively. Fourth and fifth metatarsals 34d-e are both substantially connected to cuboid 21. Toes 40a, 40b, 40c, 40d, 40e are hingedly attached to the metatarsals for significant movement.

The ground support phase of a running step generally includes a braking phase, a stance phase, and a propulsive phase. The braking phase occurs when the foot makes first contact with the ground and the foot begins to flatten. The stance phase follows the braking phase and is generally considered to consist of the time when the foot flattens and the runner's center of gravity is generally located above the foot. The propulsive phase is characterized by the rising of the heel from the ground and the shifting of the runner's weight to the ball and toes of the foot.

As to be expected of the running population, there are many different running styles. Nevertheless, approximately eighty percent of the running population makes first contact with the ground along the rear lateral corner 53 of the sole when running at moderate speeds. Individuals having this running style are commonly referred to as rearfoot strikers. By and large, the remaining twenty percent of the running population generally makes first contact along the lateral side of the sole. Often, first ground contact for these runners will occur at or between proximal head 31e of fifth metatarsal 34e and metatarsal-phalangeal joint 35e.

With respect to a rearfoot striker, the foot at heel strike is typically oriented with big toe 40a pointing upward and slightly outward (Fig. 5). From the moment heel strikes the ground, and through the braking and stance phases, the foot rotates inwardly (i.e., the foot everts or pronates) and toward the midline of the body adducts). During the propulsive phase, the foot rotates outward (i.e., inverts or supinates) and away from the midline of the body (i.e., abducts). This general description, however, vari s with differing circumstances. For instanc , running on an uphill grade tends to cause the

footpath to deviate in a manner so as to caus gr ater abduction of the foot. Running on a downhill grade tends to cause the footpath to deviate in a manner as to cause greater adduction of the foot.

For a rearfoot striker, the plantar cent r of pressur path 55a normally proceeds from the point of first contact 53 towards the midline of the foot and exits between the first and second toes 40a, 40b (Fig. 6). This action reflects the fact that the individual has maintained balance and stability during the ground support phase. While eversion of the foot in this context is a natural action, excessive eversion or an excessive rate of eversion is sometimes associated with injuries among runners and other athletes. A deviation of the center of pressure path to beneath the first toe 40a can be indicative of excessive eversion.

Figures 15-17 each sets forth a map of plantar pressures applied to the foot of a rearfoot striker running at slow speeds. The provided results are a composite of the pressures applied during the entire ground support phase. These results are single samples to represent the general distribution of pressures during running. Figure 15 indicates the pressures applied for an individual having a normal or average arch. Figure 16 illustrates the pressures applied for an individual having a high arch. Figure 17 sets forth the pressures applied for an individual having a flat foot. The incremental units in each illustrated map represent approximately a 25 square mm area. As indicated in the figures, the represented pressure readings are indicated in kilopascals (KPa). As is evident in all of the examples, the areas of highest pressure are located generally under the heel, the ball area and the big toe. Nevertheless, these maps are representative of applied pressures, irrespective of whether any of the pressures are applied as impact loads.

For a midfoot striker, first contact with the ground 56 is commonly made near proximal head 31e of fifth metatarsal 34e (Fig. 7). With these runners, the plantar center of pressure path 55b generally moves to the midline of the foot and then exits between the first and second toes 40a, 40b. For a forefoot striker, first contact with the ground 57 is often proximate the fifth metatarsal-phalangeal joint 35e (Fig. 8). The center of plantar pressure path 55c for this type of runner often moves rearward towards the midline of the foot before moving forward and exiting between the first and second toes 40a, 40b.

Moreover, an individual characterized as a rearfoot striker when running at slow or moderate speeds will often modify their technique to become a midfoot striker, and subsequently, a forefoot striker when running at ever increasing speeds. Further, when an individual is in a full sprint as on the straightaway of a running track, the initial point of contact between the foot and the support surface 58 may be near the distal head 33b of the second metatarsal 34b (Fig. 9). Th plantar center of pr ssure path 55d can then proceed dir ctly anteriorly betw en the first and second toes 40a, 40b.

Up until about the 1970's, athletic shoes by and large lack d sufficient cushi ning. Consequently, injuri s w re sustained by thos ngaging in athletic activities. To overcome these shortcomings, manufactur rs focused their attention upon enhancing the cushioning provided by athletic shoes. To this end, midsoles have over time been increased in thickness. These endeavors have further led to the incorporation of other cushioning elements within the midsoles and other sole configurations intended to provide enhanced cushioning effects. The industry's focus on improving the cushioning effect has resulted in a marked improvement of shoes in this regard. Nevertheless, footwear stability with respect to lateral and rotative movements has not always been successfully addressed. In fact, the benefits realized in cushioning have sometimes led to a degradation of the shoe's stability.

Inadequate running stability, like inadequate cushioning, can result in an increased risk of injury. As discussed above, undue amounts of eversion or inversion, or excessive rates of eversion or inversion, can lead to injuries for runners. Moreover, forces generated between the foot and the ground during the ground support phase can also produce visible and generally equal and opposite physical reactions in the lower extremities during the subsequent flight phase. For example, severe inward or outward rotation of the foot during the propulsive phase can produce rotative or counter-rotative movements in the lower extremities during the flight phase. These generally inefficient movements, commonly called "whips" by athletic coaches, can also be associated with an increased potential for injury.

In an effort to provide greater stability, some shoe soles have in the past included cushioning materials having differing degrees of stiffness. In general, the stiffer materials have been provided in an effort to prevent excessive eversion of the forefoot. As one example, U. S. Patent No. 4,364,189 to Bates discloses a sole wherein a stiffer foam material is provided along the medial side of the foot. This design, however, fails to recognize and adequately address impact forces, high vertical loading, and plantar pressures found under the distal heads of the first and second metatarsals, the sesamoids, and the proximal heads of the proximal phalanges of the first and second toes. As a result, enhanced stability is gained at the price of degrading the quality of cushioning afforded to the user's forefoot.

U.S. Patent Nos. 4,551,930 to Graham et al. and 4,128,950 to Bowerman et al. disclose athletic shoes wherein the soles have a plurality of foam materials which provide different degrees of stiffness in compression. In the Graham shoe, the stiffer foam material is positioned about the entire perimeter of the sole. In the Bowerman shoe, the stiffer foam material is positioned about the perimeter of the heel area. While enhanced stability is provided by th se shoes, the stability is again gained at the expense of cushioning. In particular, the

introduction of materials having a great r r lativ stiffness in compression about the heel reduces the potential cushioning available during heel strik .

SUMMARY OF THE INVENTION

Numerous studies have been conducted to determine which areas along the foot experience the highest plantar pressures during running. However, the mere existence of a high plantar pressure is not necessarily indicative of a need for enhanced cushioning materials or devices affording relatively low stiffness in compression. A high pressure area which is not the result of a sudden impact is not associated with the same level of acceleration and shock as one which is associated with a sudden impact.

The present invention enables provision of a sole having the ability to provide both stability and cushioning in order to enhance performance and lessen the risk of injury. The sole of the present invention includes cushioning regions with different levels of stiffness at selected locations with respect to the anatomy and skeletal structure of the foot. Cushioning elements with a lesser relative stiffness in compression are positioned at locations most likely to experience impact loads during running and like activities. Cushioning elements with a greater relative stiffness in compression are positioned at locations where impact loads are unlikely and greater resistance is needed to stabilize the running motion.

The invention provides in one aspect a sole for a shoe or other footwear having a first cushioning region of relatively lesser stiffness in compression and a second cushioning region of relatively higher stiffness in compression. The first cushioning region is arranged to underlie at least a substantial portion of the ball of the foot. The second cushioning region comprises a generally C-shape area of the sole adjacent to the medial side of the sole.

Further aspects and embodiments of the invention are set forth in the claims. The features of the dependent claims represent preferred embodiments of each aspect of the invention.

The present invention is further described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a top or dorsal view of the bones of the foot

Figure 2 is a medial side view of the bones of the foot.

Figure 3 is a bottom or plantar view of the bones of a foot.

Figure 4 is a lateral side view of the bones of a foot with the second through fifth phalanges omitted for clarity of view of the hallux.

Figure 5 is a rear view of a typical rearfoot striker.

Figur 6 is a top view of the bones of a foot (with only the bones of the forefoot shown in detail) illustrating the plantar center of pressure path for an individual characterized as a rearfoot striker.

Figure 7 is top view of th bon s of a foot (with only the bones of the forefoot shown in detail) illustrating the plantar center of pressure path for an individual characterized as a midfoot striker.

Figure 8 is top view of the bones of a foot (with only the bones of the forefoot shown in detail) illustrating the plantar center of pressure path for an individual characterized as a forefoot striker.

Figure 9 is top view of the bones of a foot (with only the bones of the forefoot shown in detail) illustrating the plantar center of pressure path for an individual in a full sprint on a straightaway.

Figure 10 is a top view of the sole of one embodiment of the present invention illustrating the locations of the differential cushioning regions with respect to the skeletal structure of the foot (with only the bones of the forefoot shown in detail).

Figure 11 is a top view of an alternate construction of the sole.

Figure 12 is a top view of a sole of another embodiment of the present invention illustrating the locations of differential cushioning regions with respect to the skeletal structure of the foot (with only the bones of the forefoot shown in detail).

Figure 13 is a top view of another alternative construction of the sole which includes the use of a moderator.

Figure 14 is a cross-sectional view of an athletic shoe taken along line 14-14 in Figure 13.

Figure 15 is a map of plantar pressures for a rearfoot striker having a normal arch.

Figure 16 is a map of plantar pressures for a rearfoot striker having a high arch.

Figure 17 is a map of plantar pressures for a rearfoot striker having a flat foot.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention pertains to footwear 60 having an upper 63 and a sole 70 (Fig. 14). The upper can have a number of different constructions. In the preferred embodiment, upper 63 has a conventional athletic shoe construction including a rear or heel end 64, a front or toe end 65, a tongue 66 and a row of eyelets 67 (Fig. 14). Nonetheless, the upper may also consist of straps (e.g., a sandal) or other constructions suitable for securing the footwear to a foot. Upper 63 is secured to sole 70 having an outsole 68, a midsole 69 and an insole 74.

The sole of the present invention is formed with regions which exhibit differential stiffness in compression. The regions which provide a lesser relative stiffness in compression are positioned beneath those portions of th foot which ar most lik ly to xperience sudden impacts during running and lik activities. Shock waves

gen rated by an impact travel at a rate exc eding 1500 met rs/second in soft tissue, and at a rat exceeding 3000 m ters/second in bone. Accordingly, a soft cushion is n eded proximate the point of impact to provide a rapid and suffici nt cushioning response. Cushions with a great r relative stiffn ss in compression are positioned at locations where sudden impacts during running activity are unlikely, and where running stability can be enhanced.

In one preferred embodiment, a sole 70 for footwear has a forefoot portion 71 formed with cushioning regions 72, 73 having different degrees of stiffness in compression (Fig. 10). Cushioning region 72 has a lesser relative stiffness in compression than cushioning region 73 in order to provide greater cushioning during running. Cushioning region 73 offers a firmer cushion in order to provide the foot with greater stability.

The drawings therefore, illustrate a sole 70 of the invention. The sole 70 has a medial side. a lateral side and first 72 or 72' and second 73 or 73' cushioning regions. The first cushioning region 72 or 72' has a lesser stiffness in compression than the second cushioning region 73 or 73' and underlies at least a substantial portion of the ball 42 of the foot. The second cushioning region 73 or 73' comprises at least a roughly C-shape area of the sole 70 adjacent the medial side of the sole 70.

The C-shape 73 or 73' may typically be described as surrounding a medial end, slightly spaced from the medial side of the sole 70, of the first cushioning region 72 or 72'

In any event, in one embodiment the C-shape area 73 or 73' has within the "C" an area of the first cushioning region 72 or 72' arranged to underlie the first metatarsal-phalangeal joint 35a (including the distal head 33a of the first metatarsal 34a and the proximal head 44a of the first proximal phalange 45a). More desirably in this embodiment. the first cushioning area is arranged to underlie at least a substantial part of the ball 42 of the foot, including the sesamoids 36a-b, the distal heads 33a-e of the metatarsals 34a-e, each metatarsal-phalangeal joint 35a-e and the proximal head 44a-e of each proximal phalange 45 a-e; the C-shape area or portion is arranged to underlie the foot generally surrounding the first metatarsal-phalangeal joint 35a to the radial side of the sole 70, including the shaft 49a of the proximal phalange 45a of the first toe 40a and at least a portion of the shaft 32a of the first metatarsal 34a.

In another embodiment, the first cushioning region 72 or 72' is typically arranged to underlie at least a portion of the ball 42 of the foot which includes the sesamoids 36a-b, the distal head 33a-e of each metatarsal 34a-e, each metatarsal-phalangeal joint 35a-e and the proximal head 44a-e of each proximal phalange 45a-e. while the C-shape area is arranged to underlie a medial area of the foot which generally embraces the first metatarsal-phalangeal joint 35a and includes the shaft 49a of the proximal phalange 45a of the first toe 40a and th shaft 32a (or a portion thereof) of the first metatarsal 34a.

In a further mbodiment, the first cushioning region 72 or 72' is arranged to underlie a portion of the ball 42 extending to and along the lateral side of th sol 70 at and between th proximal head 44e of the fifth proximal phalange 45e. The first cushioning region 72 or 72' has a medial end extending almost to the medial side of the sole 70. The C-shape (or U-shape) portion is arranged to underlie the foot generally surrounding the medial end of the first cushioning region 72 or 72'.

It will be seen therefore that the invention includes a sole 70 having a cushioning portion of lesser stiffness in compression positioned to underlie the ball of the foot (or at least a substantial part thereof) and having a medial end which is spaced slightly from the medial side of the sole, a medial end portion of the cushioning element being embraced by a cushioning portion of higher stiffness in compression.

In the embodiment of Fig.10, the cushioning region 72 is generally shaped to underlie second and third toes 40b, 40c in toe area 43, a substantial portion of ball area 42, an anterior portion of shafts 32a-c, and shafts 32d-e and proximal heads 31d-e of fourth and fifth metatarsals 34d-e. As discussed earlier, ball area 42 includes sesamoids 36a-b, distal heads 33a-e of metatarsals 34a-e, metatarsal-phalangeal joint 35a-e. and proximal heads 44a-e of proximal phalanges 45a-e. Cushioning region 72 extends along the lateral side wall 76 of the sole so as to cushion the shock associated with first ground contact for midfoot and forefoot strikers . Since the first ground contact is made along the lateral side wall 76, cushioning region 72 could be limited to underlie only fifth metatarsal 34e, instead of both metatarsals 34d-e. However, in order to enable easier manufacturing and a better transition during running activity, cushioning region 72 can underlie fourth metatarsal 34d as well.

Cushioning region 73 preferably includes a pair of discrete sections 73a, 73b. Cushioning section 73a comprises a C-shaped area and is positioned to lie underneath a portion of the foot as to generally surround metatarsal-phalangeal joint 35a adjacent medial side wall 77, and underlies first toe 40a, and the posterior portions of metatarsals 34a-c. Cushioning section 73b underlies fourth and fifth toes 40d-e. More specifically. cushioning region 73 underlies: shafts 49a, 49d, 49e and distal heads 48a, 48d, 48e of proximal phalanges 45a. 45d, 45e: middle phalanages 47d, 47e, distal phalanges 46a, 46d,46e, the medial side portion 79 adjacent metatarsal-phalangeal joint 35a; and proximal heads 31a-c and a portion of the shafts 32a-c of metatarsals 34a-c.

Although high pressures are associated with the medial side of the sole. particularly under big toe 40a and adjacent first metatarsal-phalangeal joint 35a, these areas are not likely to experience substantial and sudden impact loading during running. As discussed above, first contact with the ground ordinarily occurs in the rearfoot area as shown in Fig. 6 at 53, along lat ral

sid wall 76 as shown in Figs. 7 and 8 at 56 and 57, respectiv ly, or in the centre portion of ball area 42, as shown in Fig. 9 at 58. As a r sult, th level of shock generat d along medial side wall 77 of th sol is much less than that gen rated along lateral side wall 76. Consequently, use of a firmer cushion along the medial side wall does not detrimentally affect the sole's ability to provide adequate cushioning protection for the foot.

By providing a firmer cushion along medial side wall 77, the sole is able to offer resistance to the lateral rolling of the foot, i.e., eversion, and provide a better support for the foot. The medial portion of the foot, and especially big toe 40a, play a predominant role in an individual's ability to prevent excessive eversion and stabilize the foot.

Cushioning region 73 also includes cushioning section 73b along lateral side wall 76 to underlie toes 40d-e. More specifically, cushioning section 73b of cushioning region 73 underlies shafts 49d-e and distal heads 48d-e of proximal phalanges 45d-e, middle phalanges 47d-e, and distal phalanges 46d-e. Although impact forces are ordinarily associated with lateral side wall 76, first contact with the ground generally occurs rearward of toes 40d-40e. Accordingly, a firmer cushion can be provided beneath toes 40d-40e to resist excessive inversion of the foot during the latter portion of the propulsive phase as the foot is commonly inverted and abducted.

Extending cushioning region, 72 which provides a lesser relative stiffness in compression, to underlie toes 40b, 40c can be advantageous. Although, substantial impact forces are not likely to be imposed on toes 40b, 40c, the use of a softer cushion between the two firmer sections 73a, 73b of cushioning region 73 can provide a cradling effect to assist in guiding the center of pressure in relation to the foot so as to afford stability.

Nevertheless, there are times when a firmer cushion may be desired under the entire toe area 43, including the portion underlying toes 40b, 40c. For instance, at high running speeds (e.g., sprinting activity) a reduction in ground contact time is a high priority, as such generally results in faster running performances. The use of a firmer toe area can provide a faster transition during the propulsive phase.

While the above-described embodiment is the preferred construction, the size and shape of regions 72, 73 can be varied. For instance, regions 72, 73 can be limited to forefoot areas located rearward of toe area 43, or to areas forward of about the midpoint of shafts 32a-e of metatarsals 34a-e. In either case, the shape of the regions would remain generally the same as in the preferred embodiment, except for the noted limitations.

As another alternative. the cushioning regions could also be limited to an area substantially about ball area 42 (Fig. 12). In this construction, a cushioning area 72' of lesser relative stiffness in compression generally underli s the ant rior portions of shafts 32b-e, a small anterior portion of th shaft 32a, and a substantial portion of ball area 42 including the metatarsal-phalangeal joints 35a-e and sesamoids 36a-b. Cushioning area 73' of greater relative stiffn ss in compression has a generally C-shaped configuration which underlies a portion of shaft 49a, medial side portion 79 adjacent metatarsal-phalangeal joint 35a, and a portion of shaft 32a As with the other embodiments, cushioning area 72' extends to lateral side wall 76' of sole 70', but lies short of medial side wall 77'. The C-shaped configuration of cushioning region 73' then wraps about the medial end 80' of cushioning region 72'.

The differential cushioning provided by regions 72, 73 or 72', 73' can be provided in a wide variety of ways. In the preferred construction, differential cushioning is substantially provided by the cushioning elements of the sole. These cushioning elements can be composed of foam materials, fluid-filled bladders, or other cushioning devices used singularly or in combination with other elements. In the most preferred embodiment, the sole is substantially composed of fluid-filled bladders. The fluid-filled bladders can be at least partially encapsulated in a foam material. The bladders are preferably fabricated in accordance with the teachings of U.S. Patent Nos. 4,183,156, 4,219,945, and 4,340,626 to Rudy, which are hereby incorporated by reference. Nevertheless, other types of bladder constructions could also be used.

According to the preferred construction, bladders inflated to different internal pressures are arranged to cover the two respective cushioning regions 72, 73. Preferably, the bladder (or bladders) defining cushioning region 72 is inflated to an internal pressure of 1-15 psi, and most preferably about 10 psi. The bladder (or bladders) defining cushioning region 73 is preferably inflated to 15-50 psi, and most preferably about 25 psi. Nonetheless, other pressures could be used depending upon the volume of the respective bladders and the intended athletic application. The different inflation pressures provide the different degrees of stiffness desired to obtain the above-discussed cushioning and stability objectives. Generally, as discussed in U.S. Patent Nos. 5,343,639 and 5,353,523, which are hereby incorporated by reference, the pressure and volume of the bladders are chosen to provide an air spring stiffness in compression on the order of less than or equal to about 20 N/mm at the time of initial impact and about 70-100 N/mm at the time of maximum loading for cushioning region 72, and on the order of about twice that stiffness in compression for cushioning region 73. Of course, cushioning elements with different levels of stiffness in compression could be used.

The cushioning elements forming cushioning regions 72, 73 can be composed of a single element or a plurality of elements. For instance, each region 72, 73 can be formed of a single open bladder, a single bladder with a plurality of chambers, or a plurality of bladders. The chambers may be fluidly-interconnected or closed to on another. In the pr ferred embodiment, cushioning region 72 is covered by a fluid-filled bladder 176 having

a plurality of closed chambers 176a, 176b, 176c, 176d (Fig. 11). Of course, other combinations and numbers of chambers could be used. Similarly, cushioning region 73 is covered by a fluid-fill d bladder 177 having closed chamb rs 177a, 177b. During fabrication, chambers 177a, 177b are interconnected via conduit 181. In the preferred construction, chambers 176a, 176b, 176c, 176d, 177a, 177b are inflated at ports 183. Bladders 176, 177 can be fabricated in accordance with U.S. Patent Nos. 5,353,459 or 5,406,179, hereby incorporated by reference. However, other known manufacturing techniques could also be used.

Alternatively, in accordance with U.S. Patent No. 5,406,719, the bladder or bladders covering regions 72, 73 may all be inflated to the same internal pressure. As an example, a single bladder having a plurality of chambers can extend to cover both regions 72. 73. During fabrication, the chambers are fluidly interconnected to facilitate easy inflation. However, once inflation is complete. the ports interconnecting the chambers are closed by radio frequency welding or other means. Of course, if desired, one or more of the ports could be left open or partially open to permit the fluid to flow between the chambers. In this construction, the chambers covering region 73 would have a smaller volume than the chambers covering region 72 in order to provide a greater relative stiffness in region 73. In this way, the desired differential degrees of stiffness can be obtained with chambers inflated to the same internal pressure.

Further, the different degrees of stiffness in the sole may also be provided by other means. For example, stabilisers as taught in a co-pending U.S. Patent Application entitled "Footwear With Stabilisers" could be used to provide at least a portion of the desired differential cushioning. A copy of this co-pending U.S. Patent Application is filed with the present application; the content of the U.S. application is included in this application but the specification of the U.S. application does not form part of the published printed specification of this application. Also, as an example. moderators 83 can be used to provide the desired differential cushioning regions 72. 73 (Figs. 13 and 14). The moderators could be shaped to overlie the entire region 73 in order to spread the loads out over a greater surface area and thereby increase the stiffness of the cushion. Nevertheless, if desired, the moderator 83 could be used to cover only a portion of region 73, such as the rearward parts of section 73a. The stiffer portions of the toe area 43 could be formed with the use of stiffer midsole cushioning elements. The moderators 83 can lie between the midsole 69 and the insole 74, but could also be located in other areas of the sole. A thin auxiliary pad 84 can be provided to cover the areas left open by moderators 83 to provide an even support surface for the foot when the moderators lie over the midsole. The moderators can also be used in combination with midsole cushioning elements, such as fluid-fill d bladders 85a, 85b, which may, if desired, provide differ nt degrees of stiffness to obtain the desired overall stiffness levels. As an example, the moderators can be constructed as taught in U.S. Pat nt Nos. 4,506,460 and 4,486,964, which are hereby incorporated by ref renc . The moderators can b formed of a wide variety of mat rials including thermoplastics or other resins, cardboard, carbon fiber composites, or other suitable material.

The differential cushioning effect could also be provided by the outsole construction. For example, the outsole may be provided with lugs of differing sizes or shapes arranged in accordance with cushioning regions 72, 73. As an example, in a shoe wherein the lugs bear against a conventional foam midsole, lugs having greater surface area could be provided in region 73 as compared to the lugs in region 72. In this way, the lugs of the outsole in cooperation with the rest of the sole could provide the different levels of stiffness for cushioning regions 72, 73. Of course, other suitable outsole structures for providing the desired differential stiffening could also be used.

Soles fabricated in accordance with the present invention can also be provided with one or more lines of flexion in the forefoot area. For example, a longitudinal line of flexion 190 can extend rearward from the anterior end 192 of the sole such that big toe 40a and metatarsal-phalangeal joint 35a are located on one side of line 190 and medial toes 40b-40e and other metatarsal-phalangeal joints 35b-e on the other side (Fig.11), as taught in U.S. Patent No. 5,384,973, which is hereby incorporated by reference. As another example, a line of flexion 194 can be provided along the base of toes 40a-e (Fig. 11), as disclosed in U.S. Patent No. 4,562,651, which is also hereby incorporated by reference.

In the preferred embodiment. sole 70 further includes a cushioning region 201 of lesser stiffness in compression in the lateral, rear corner 203 (Fig.11). This construction defines a rearfoot strike zone 205 as described in U.S. Patent No. 5425184 and co-pending U. S. Patent Application entitled "Athletic Shoe with Rearfoot Strike Zone" (CIP of Serial No. 08/038,950 on which Patent 5425184 issued). A copy of this co-pending U.S. Patent Application is filed with the present application; the content of the U.S. application is included in this application but the specification of the U.S. application does not form part of the published printed specification of this application. The rearfoot strike zone 205 is a portion of the heel area of the sole delimited by a line of flexion 207 about which the rearfoot strike zone is articulated in relation to the remaining heel area. Independent articulation of strike zone 205 increases the surface area of ground contact occurring at heel strike from a narrow edge-like strip extending along the rear lateral sidewall of the sole to a wider planar area extending inwardly of the sidewall. This construction reduces medial moment and enhances both cushioning and stability. The shock associated with heel strike is reduced by the provision of cushioning means having a lesser relativ stiffness in strike zon 205. As se n in Fig. 11, a soft

cushion is also preferably provided in a section 206 directly beneath the heel.

A primary objective in th placem nt of th lin of flexion 207 is to properly delimit a rearfoot strike zone having enhanced cushioning. The rearfoot strik zone should encompass the range of heel strike locations for most rearfoot strikers, without adversely affecting medial and lateral stability during the braking, stance and propulsive phases. Since the orientation of the foot for rearfoot strikers normally causes the lateral rear corner of the sole to first engage the ground, the rearfoot strike zone is located in this corner.

On the lateral side 76 of sole 70, there is no need for the rearfoot strike zone to extend beyond the junction 209 of calcaneus 17 and cuboid 21. The medial point of rearfoot strike generally occurs well rearward of this point so that the rearfoot strike zone may be shortened if desired. Extension of a more compliant rearfoot strike zone beyond junction 209 could begin to degrade lateral stability in the midfoot region, particularly during the stance and early stages of the propulsive phase or for those exhibiting a propensity for excessive inversion. A region providing a higher relative stiffness in compression is preferably located along lateral side 76 between junction 209 and the rear lateral corner of cushioning region 72 (i.e., by proximal head 31e).

Rearfoot strike zone 205 generally need only extend toward the medial side a short distance beyond the longitudinal center of the rear side of the heel in order to accommodate the heel strike of most runners. The medial side termination point 211 of the rearfoot strike zone is conveniently described in relation to the nominal weight bearing center 213 of the heel. More specifically, medial side termination point 211 may be described in terms of an angle 0 formed between a longitudinal center axis of sole 70 and a line drawn from the weight bearing center 213 of the heel to termination point 211. Placement of the medial side termination point 211 which creates an angle θ of 10° is satisfactory to accommodate the heel strike of most rearfoot strikers. The angle θ may be increased up to about 50° for greater inclusiveness of the range of possible heel strikes. However, extension rearfoot strike zone 205 beyond this point can degrade stability, particularly for those runners exhibiting a tendency towards excessive eversion (i.e., over pronation). Therefore, cushioning elements positioned directly forward of line of flexion 207 preferably provides a greater relative stiffness in compression.

The term "line of flexion" in the application is intended to refer to a line of action, rather than a physical element of the sole about which the rearfoot strike zone occurs. The location and path of line of flexion 207 are determined by physical elements of the sole (e.g., grooves) that cooperate to provide a relatively independent articulation of rearfoot strike zone 205 relative to the remaining heel area. By delimiting rearfoot strike zone 205 with a line of flexion 207, increas d compliance within the strik zone is obtained because the strike zone is abl to pivot as a whole in addition to compressing.

With this whole sole construction, the sole can provid both cushioning and stability for all kinds of runners (including rearfoot, midfoot and for foot strikers) and at different levels of speed or running velocities. The above-discussion concerns the preferred embodiments of the present invention. Various other embodiments as well as many changes and alterations may be made without departing from the invention.

Claims

1. Footwear comprising an upper and a sole, the sole having a medial side, a lateral side, and first and second cushioning regions, the first cushioning region having a lesser relative stiffness in compression than the second cushioning region, the first cushioning region underlying at least a substantial portion of the ball of the foot including the sesamoids, the distal head of each metatarsal, each metatarsal-phalangeal joint, and the proximal head of each proximal phalange, the second cushioning region at least forming a generally C-shaped portion underlying the foot generally surrounding the first metatarsal-phalangeal joint along the medial side of the sole and including the shaft of the proximal phalange of the first toe and the shaft of the first metatarsal.

2. Footwear of claim 1 in which the first cushioning region further underlies the shaft and the proximal head of the fifth metatarsal and optionally further underlies the shaft and proximal head of the fourth metatarsal and/or in which the second cushioning region further underlies the shafts and the proximal heads of the first, second and third metatarsals.

3. Footwear of claim 1 or claim 2 in which the second cushioning region further underlies the distal head of the first proximal phalange and the first distal phalange.

4. Footwear of any of claims 1 to 3 in which the second cushioning region further underlies the shaft and the distal head of the fourth and fifth proximal phalanges, the fourth and fifth middle phalanges, and the fourth and fifth distal phalanges, and optionally in which the first cushioning region further underlies the shaft and distal heads of the second and third proximal phalanges, the second and third middle phalanges, and the second and third distal phalanges.

5. Footwear of any of claims 1 to 4 in which the first r gion includes a rear section which und rlies an outer lateral r ar corner of the sol .

6. Footwear of claim 5 in which the rear section is d - limited on its anterior edge by a lin of flexion which extends from the junction of the calcaneus and the cuboid on the lateral side to a point on th medial side which forms an angle of about 10° to 50° between the longitudinal axis of the sole and a line extending from the medial side point to the nominal plantar weight bearing centre of the heel.

7. Footwear of claim 5 or claim 6 in which the first cushioning region includes a heel section which underlies the calcaneus, and optionally in which the second cushioning region underlies portions of the foot located forward of the rear and heel sections and rearward of the proximal heads of the metatarsals.

8. Footwear of any of claims 1 to 7 in which the sole includes a midsole and an outsole, and the midsole includes at least one first cushioning element in the first cushioning region and at least one second cushioning element in the second cushioning region, wherein the first cushioning element provides a lesser relative stiffness in compression than the second cushioning element, and optionally in which the first and second cushioning elements are fluid-filled bladders.

9. Footwear of any of claims 1 to 7 in which the sole includes an outsole, a midsole, and a moderator which extends across in the midsole, wherein the moderator extends across at least a portion of the second cushioning region to provide a greater relative stiffness for the portion.

10. Footwear comprising an upper and a sole, the sole having a medial side wall, a lateral side wall, and first and second cushioning regions, the first cushioning region having a lesser relative stiffness in compression than the second cushioning region, the first cushioning region underlying at least a substantial portion of the ball of the foot and extending to and along the lateral side wall of the sole at and between the proximal head of the fifth proximal phalange and the distal head of the fifth metatarsal, the first cushioning region having a medial end extending almost to the medial side wall ofthe sole, the second cushioning region forming at least a generally C-shape portion underlying the foot generally surrounding the medial end of the first cushioning region along the medial side wall of the sole.

11. Footwear of claim 10 in which the first cushioning region extends along the lateral side wall at and between the proximal head of the fifth proximal phalang and the proximal head of th fifth metatarsal.

12. Footwear of claim 10 or claim 11 in which the second cushioning region further und rlies the first toe.

13. Footwear of claim 12 in which the second cushioning region furth r underlies the fourth and fifth toes, and optionally in which the first cushioning region further underlies the second and third toes.

14. A sole for footwear comprising a medial side and a lateral side, and first and second cushioning regions, the first cushioning region having a lesser relative stiffness in compression than the second cushioning region, the first cushioning region underlying at least a substantial portion of the ball of the foot including the sesamoids, the distal head of each metatarsal, each metatarsal-phalangeal joint, and the proximal head of each proximal phalange, the second cushioning region forming at least a generally C-shaped portion underlying the foot generally surrounding the first metatarsal-phalangeal joint along the medial side of the sole and including the shaft of the proximal phalange of the first toe and the shaft of the first metatarsal.

15. A sole of claim 14 which further includes the specific feature(s) recited in one or more of claims to 9 or 11 to 13.

16. A sole for footwear comprising a medial side wall, a lateral side wall, and first and second cushioning regions, the first cushioning region having a lesser relative stiffness in compression than the second cushioning region, the first cushioning region underlying at least a substantial portion of the ball of the foot and extending to and along the lateral side wall of the sole at and between the proximal head of the fifth proximal phalange and the distal head of the fifth metatarsal, the first cushioning region having a medial end extending almost to the medial side wall of the sole, the second cushioning region forming at least a generally C-shape portion underlying the foot generally surrounding the medial end of the first cushioning region along the medial side wall of the sole.

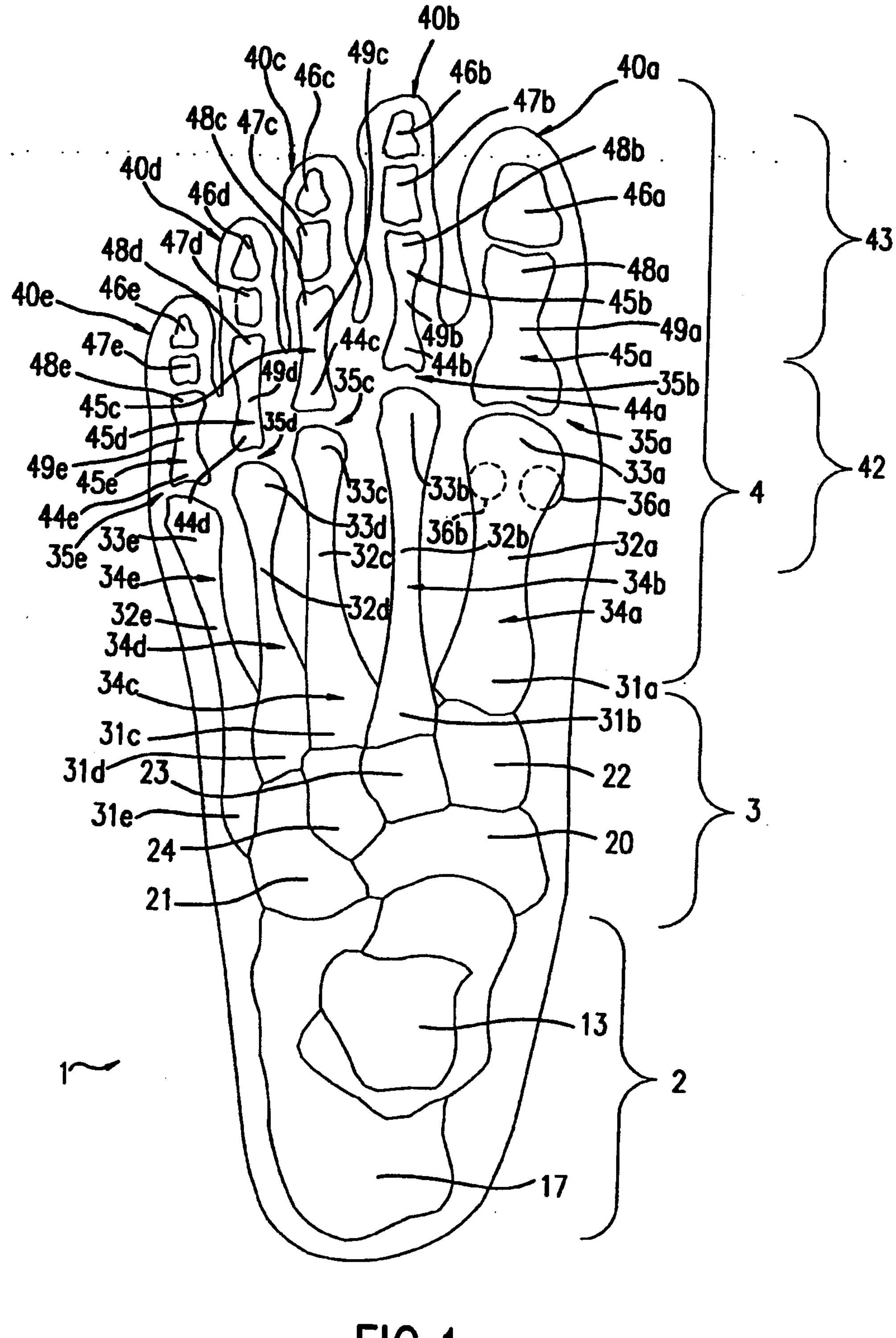
17. A sole of claim 16 in which the first cushioning region extends along the lateral side wall between the proximal head of the fifth proximal phalange and the proximal head of the fifth metatarsal.

18. A sole of claim 16 or claim 17 which further include the specific feature(s) recited in claim 12, claim 13 or both.

19. The use to provide stabilising and cushioning proprti s to a shoe sole of a cushioning portion of relatively lower stiffness in compression positioned to underlie at least a substantial part of the ball of th

foot and ext nding across the shoe front its lat ral side to a slight distanc from its medial side, and of a cushioning portion of r latively high r stiffness embracing a medial end porti n of th cushioning portion of relatively lower stiffn ss.

20. Footwear comprising a sole of any of claims 14 to 18, a sole having cushioning portions as defined in claim 19 or a sole having an arrangement of forefoot cushioning portions and optionally of rearfoot cushioning portions as shown in any of Figures 10 to 14 as interpreted by the written description thereof.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17

FIG.1

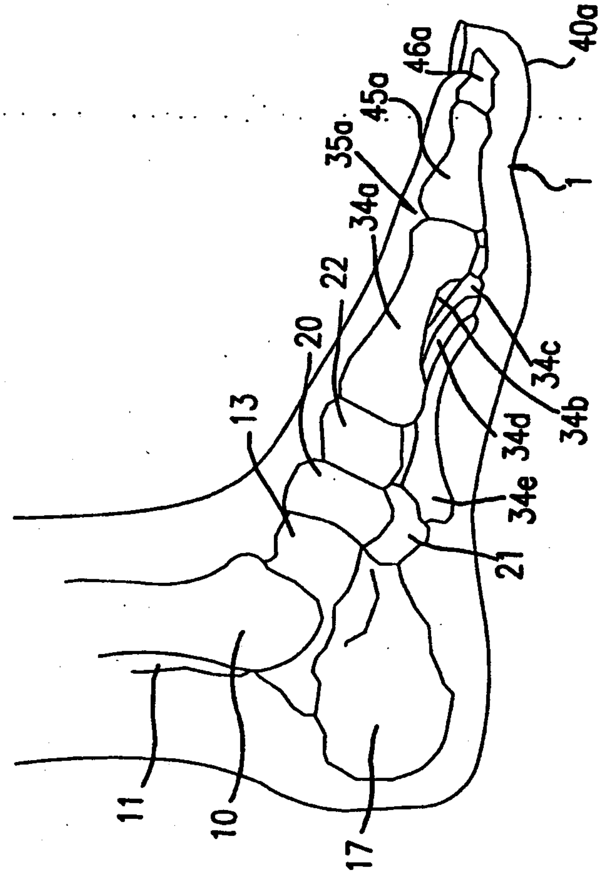
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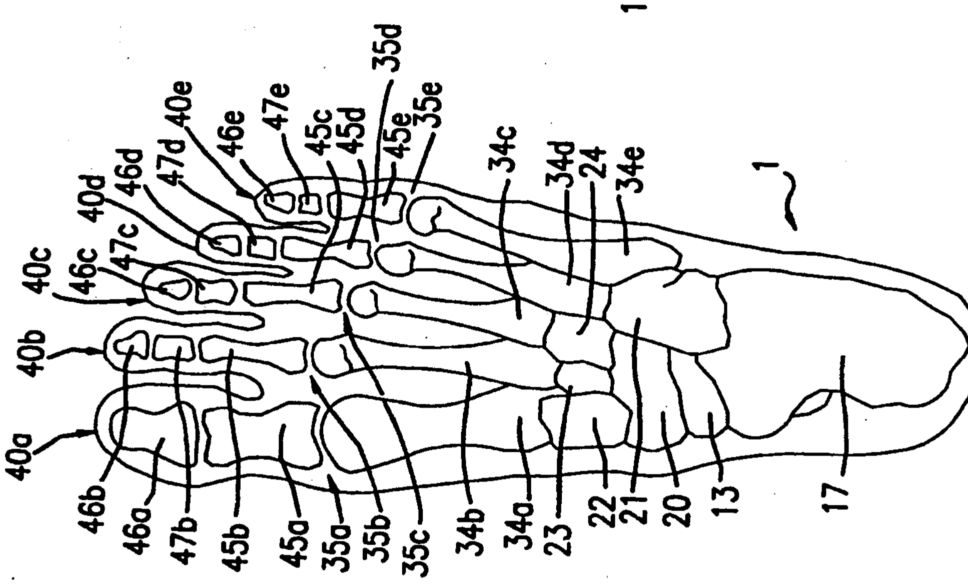
FIG. 2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17

FIG. 3

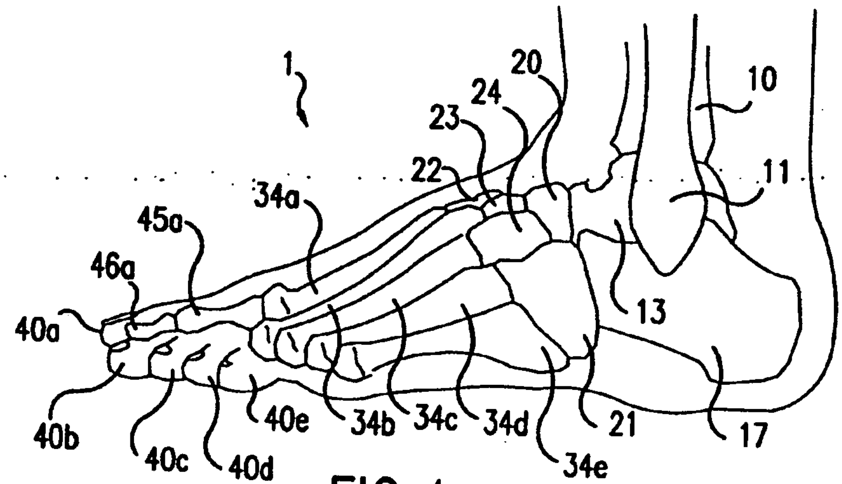


FIG.4

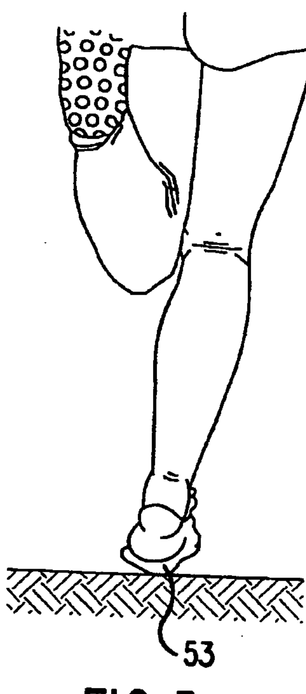


FIG.5

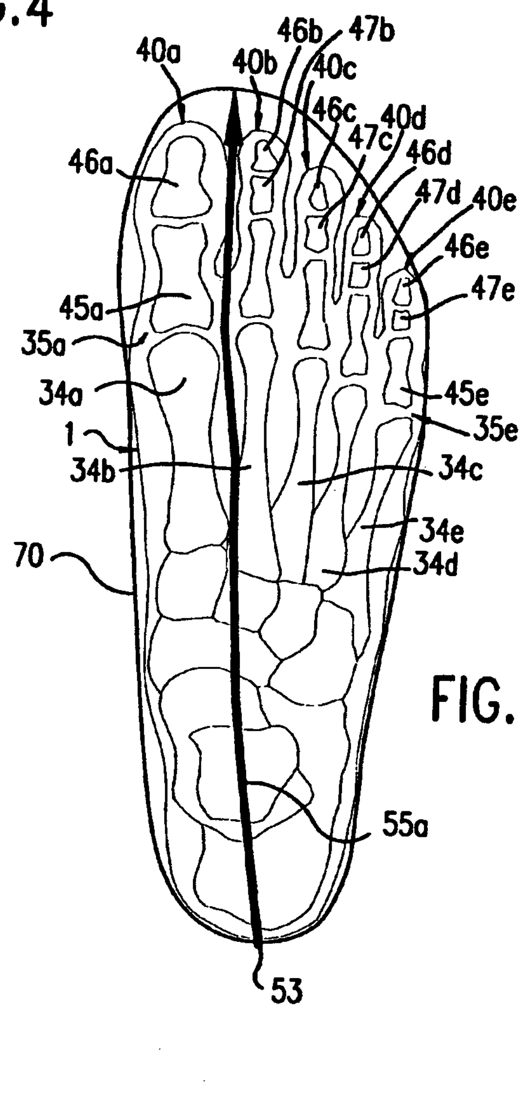


FIG.6

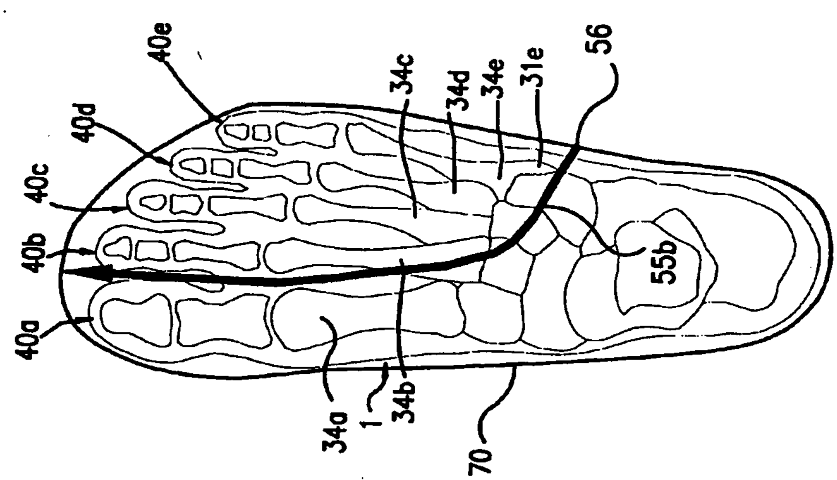


FIG.7

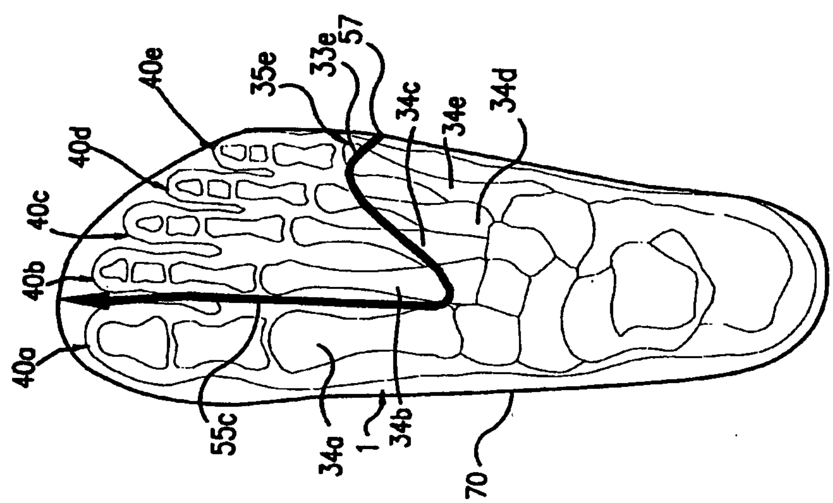


FIG.8

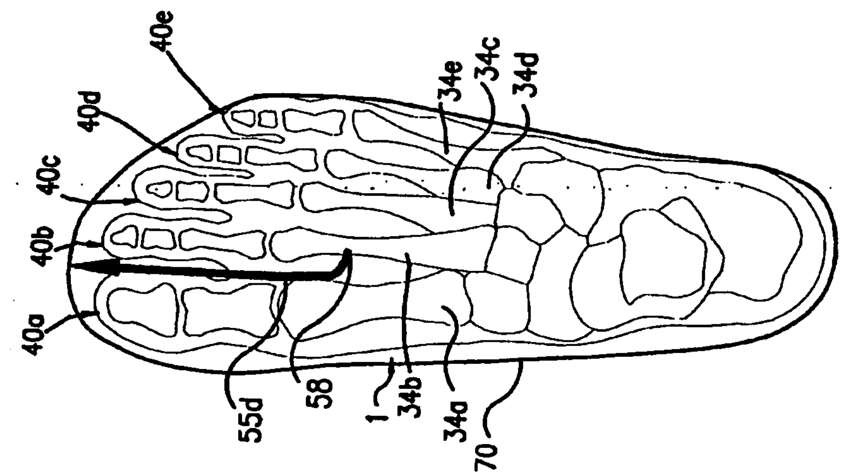
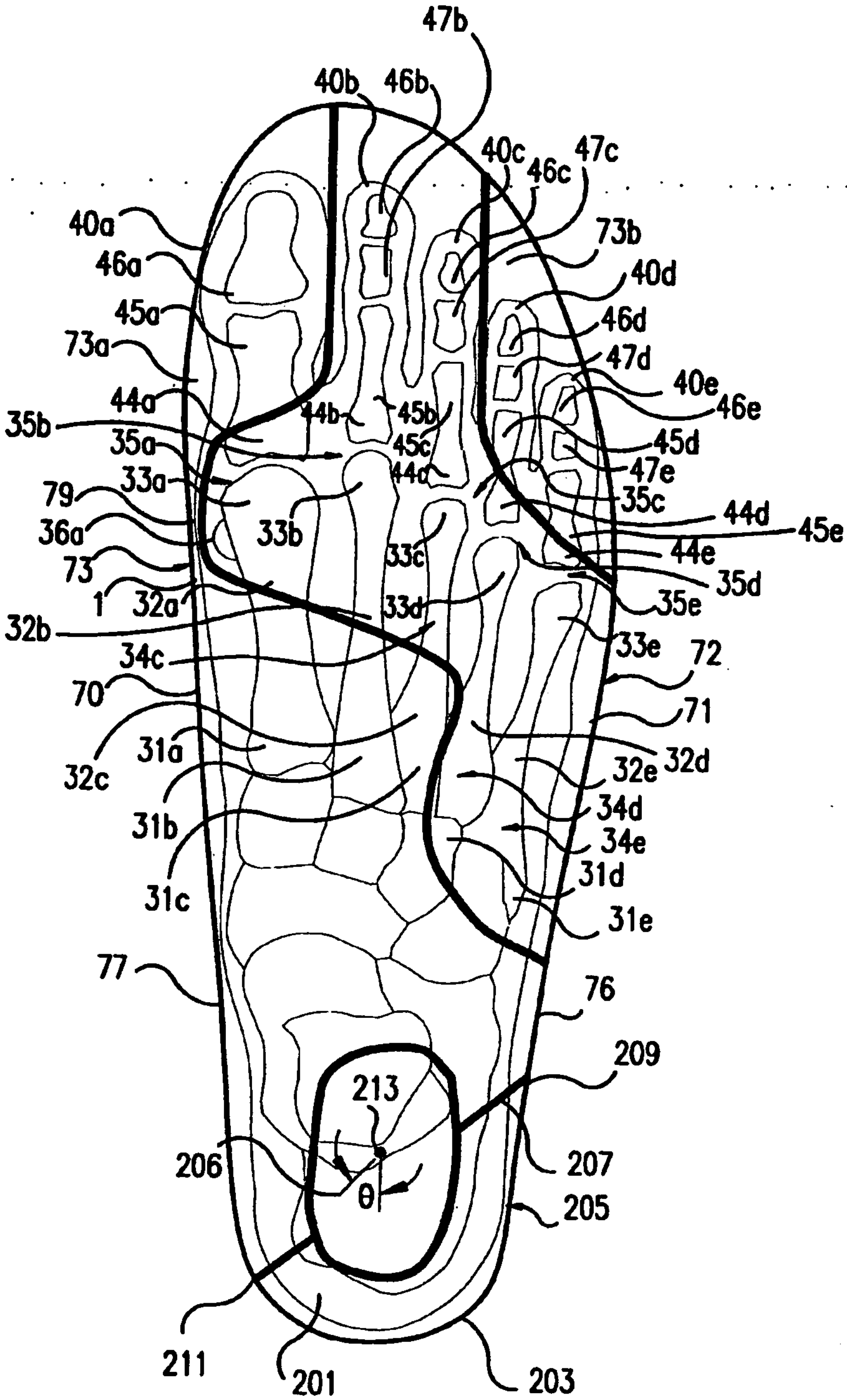


FIG.9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1
32a
33d
35e
32b
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34c
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71
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32e
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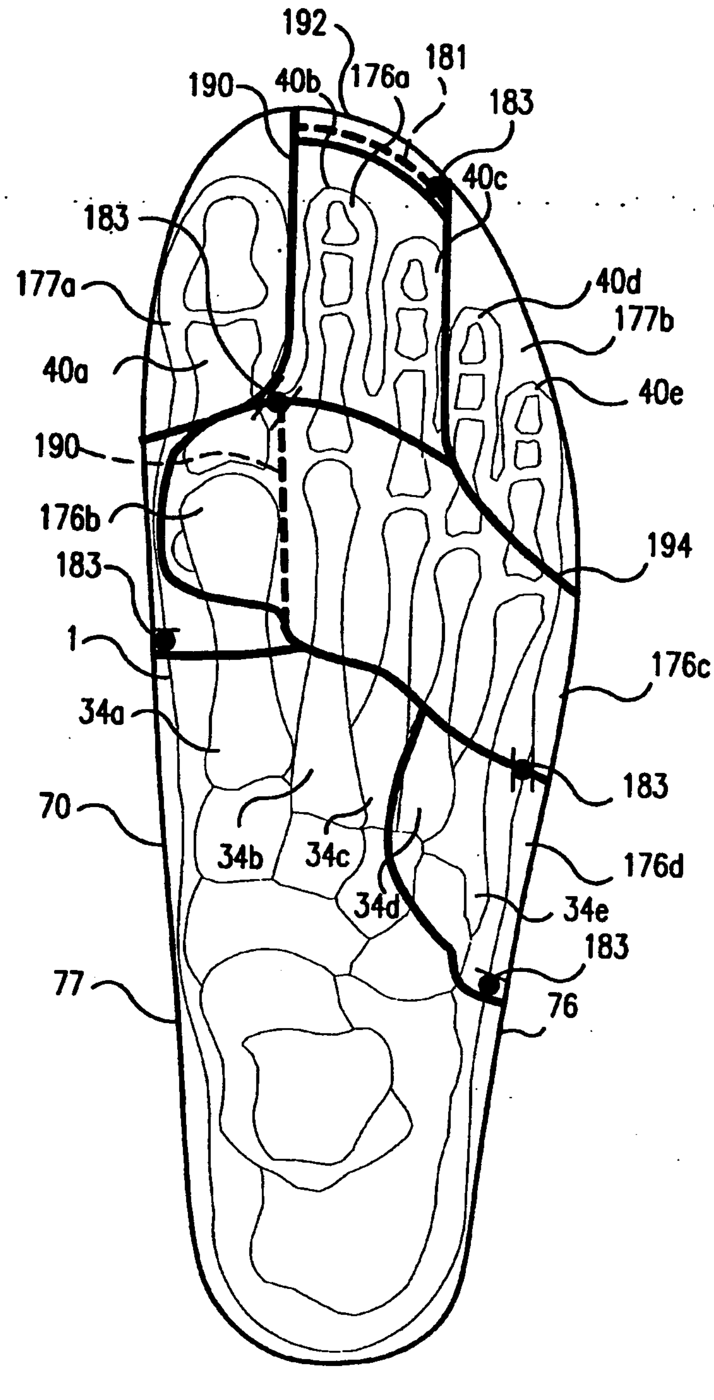
FIG.10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76

FIG.11

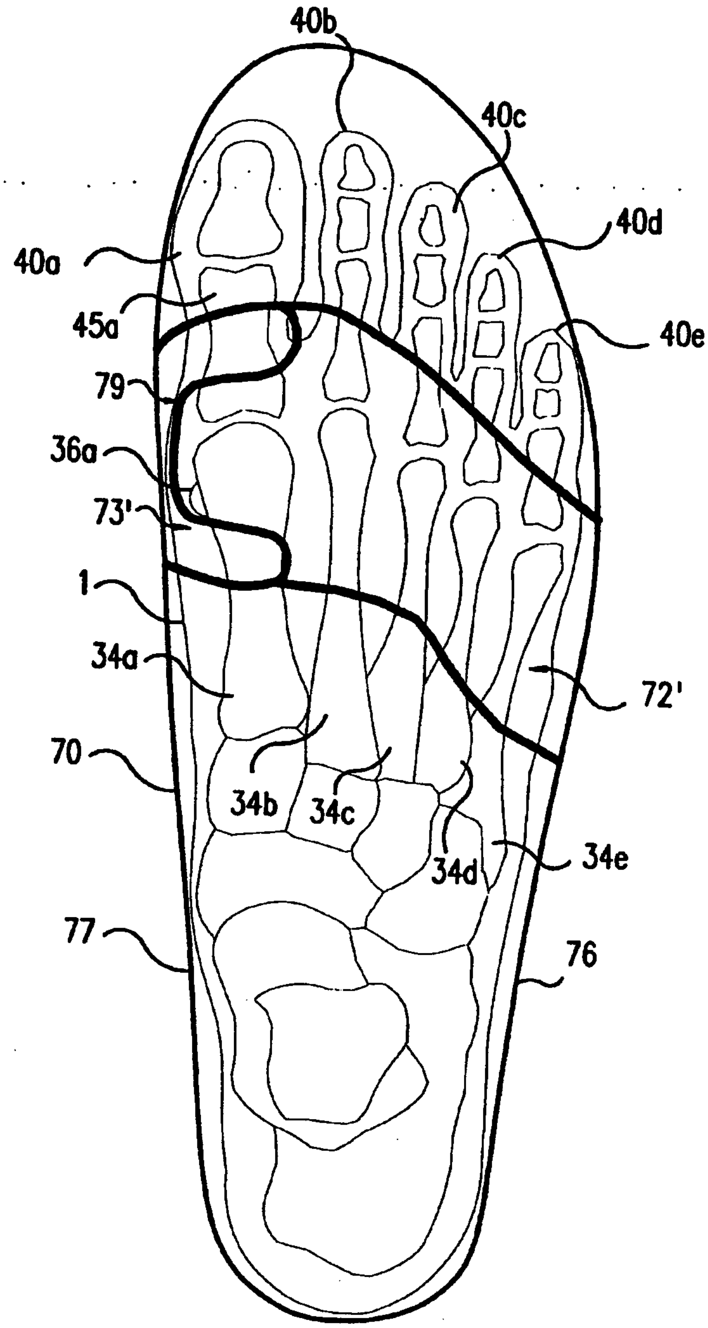
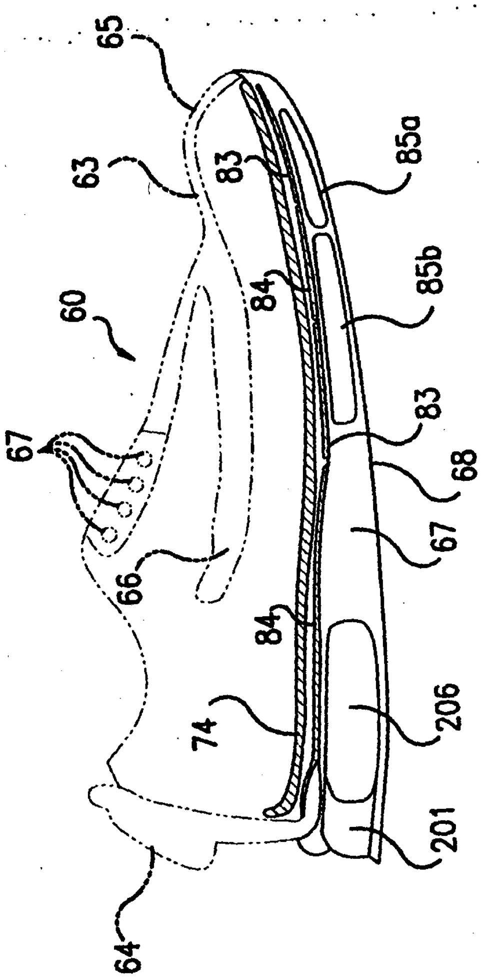


FIG.12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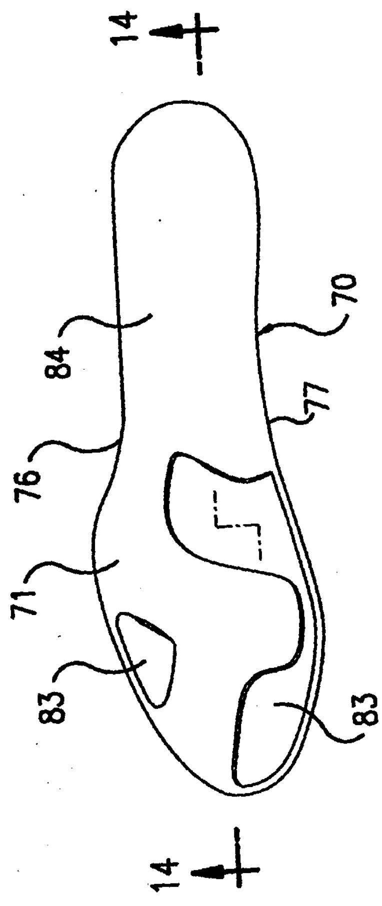
201

FIG.14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14

FIG.13

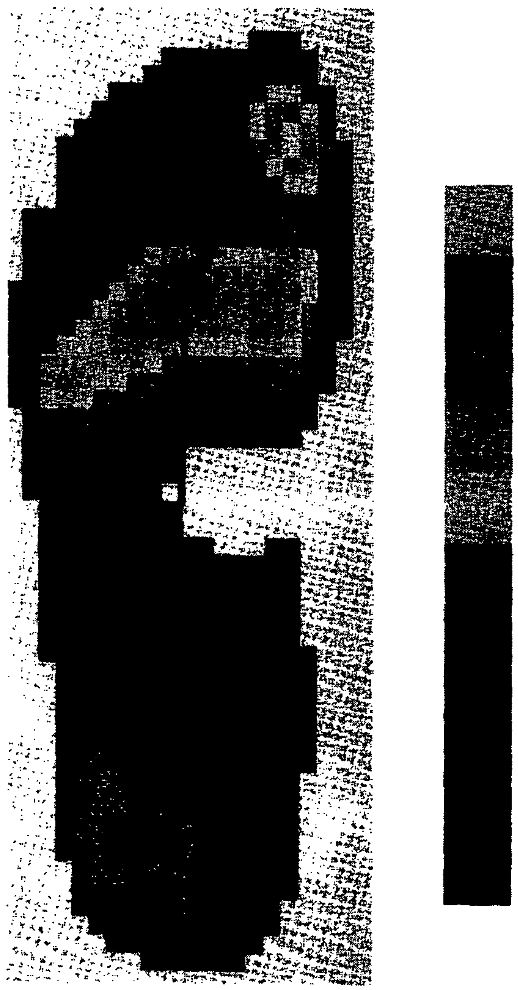

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FIG. 15

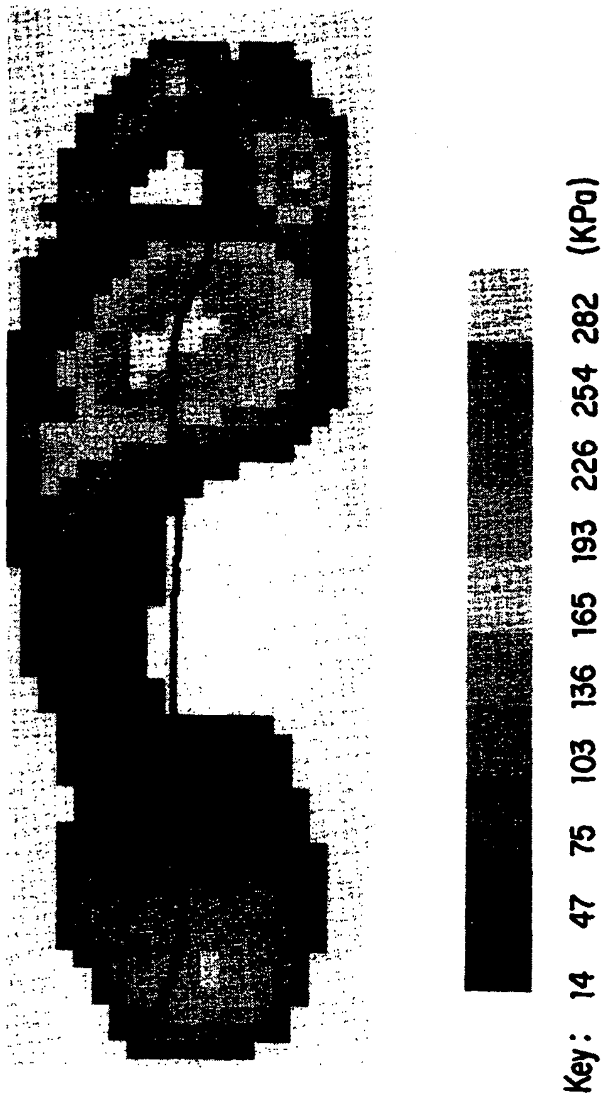

FIG.16

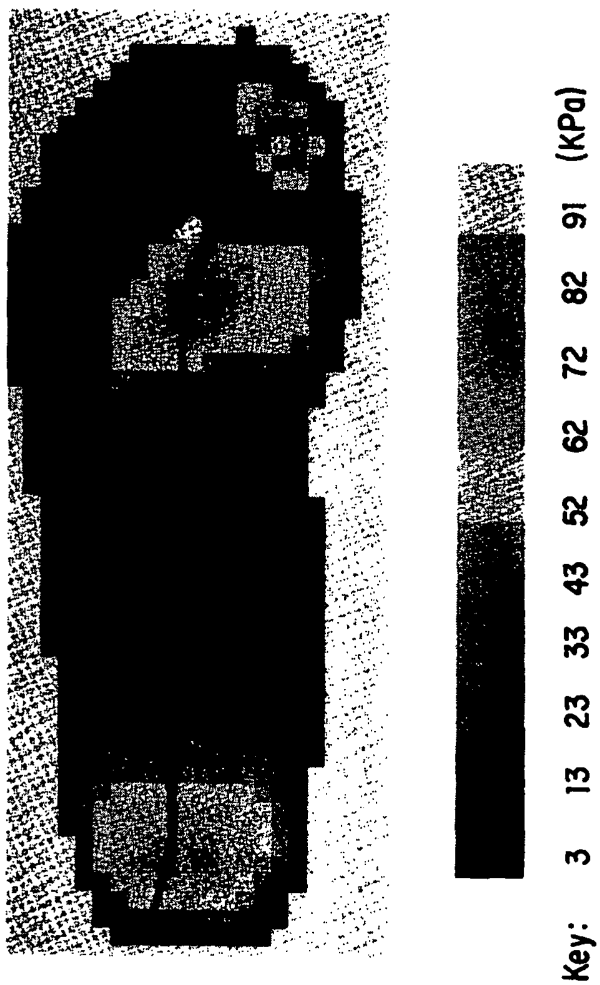

FIG.17